

Fig. 2 (Prior Art)

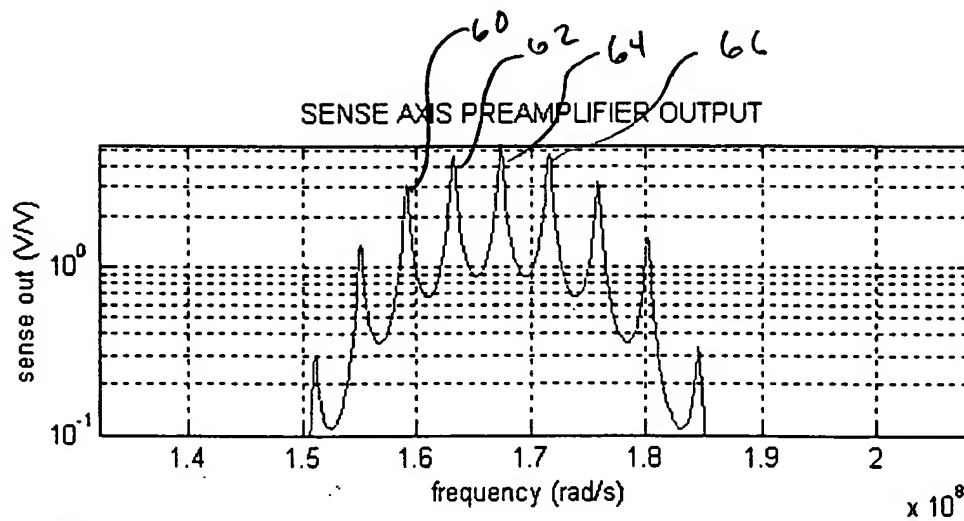


Fig. 3A

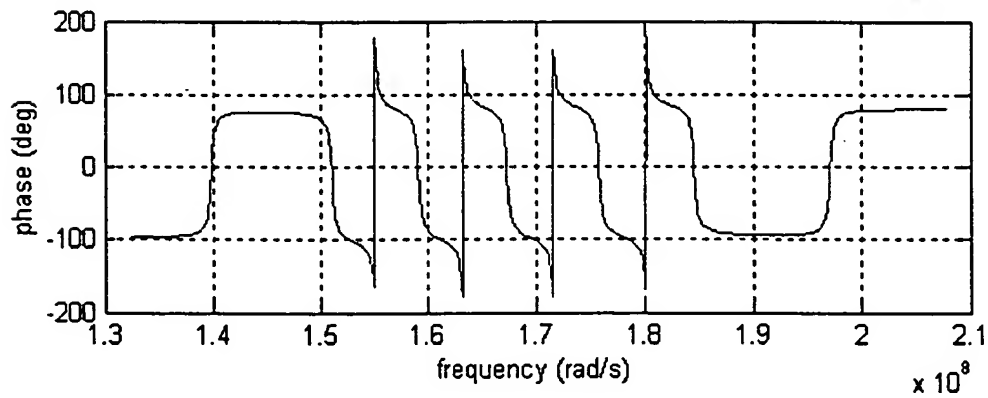


Fig. 3B

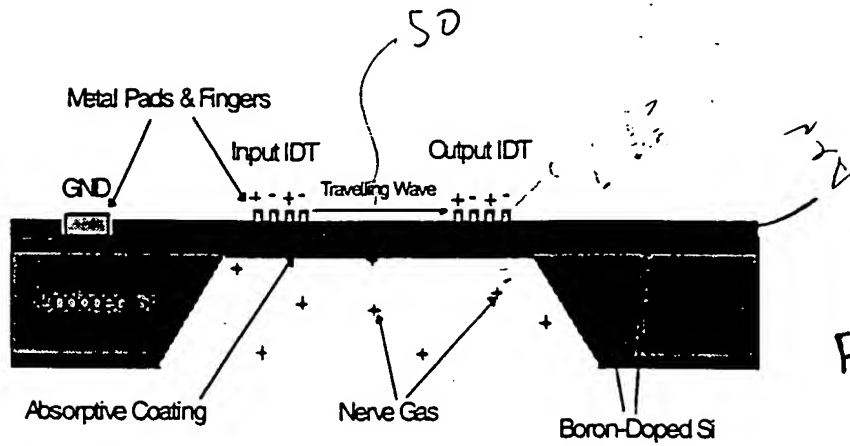


Fig. 4 (prior art)

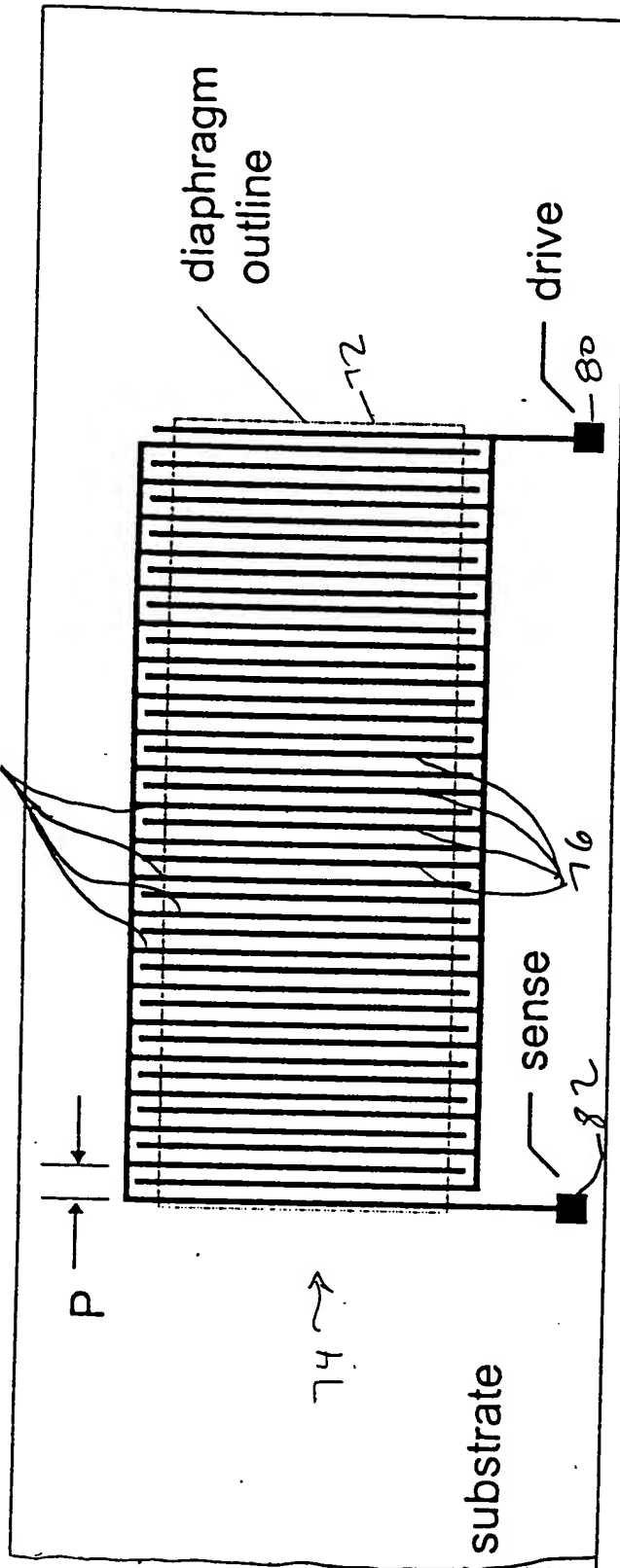


Fig. 5

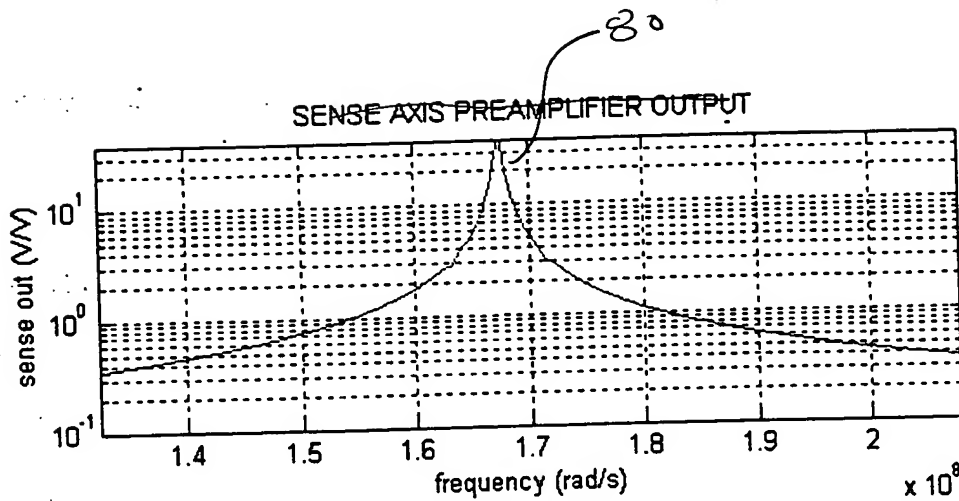


Fig. 6A

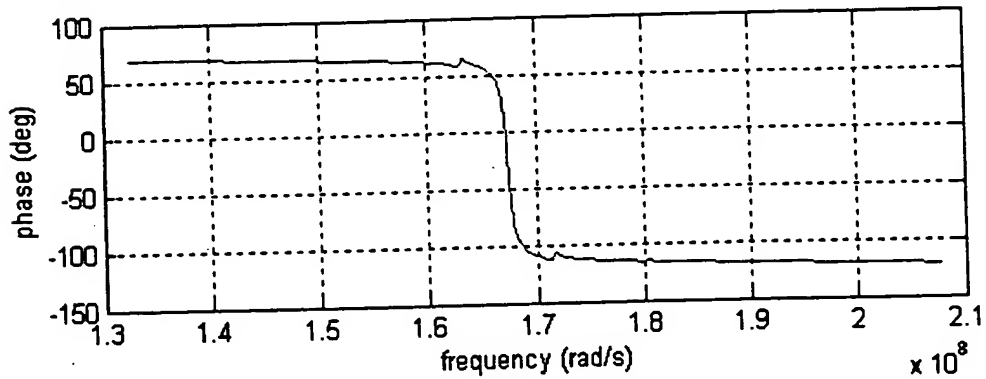


Fig. 6B

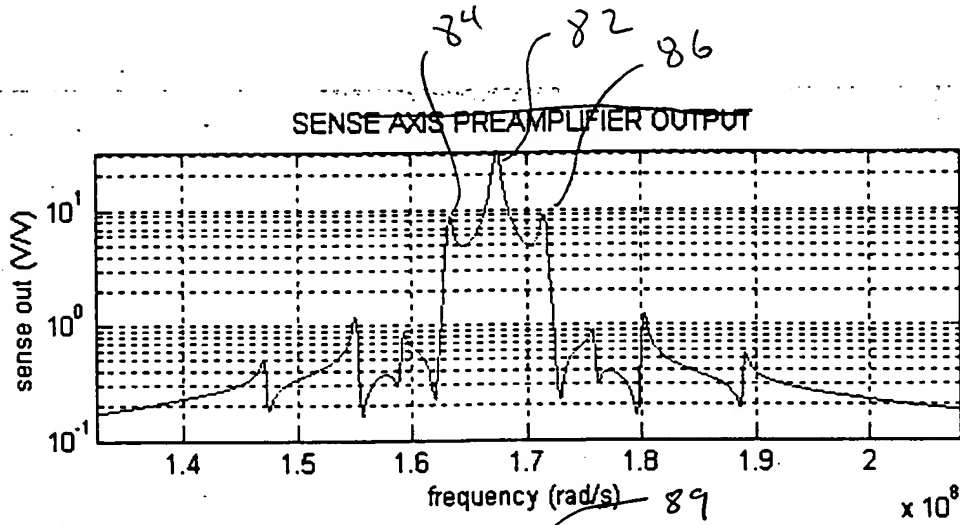


Fig. 7A

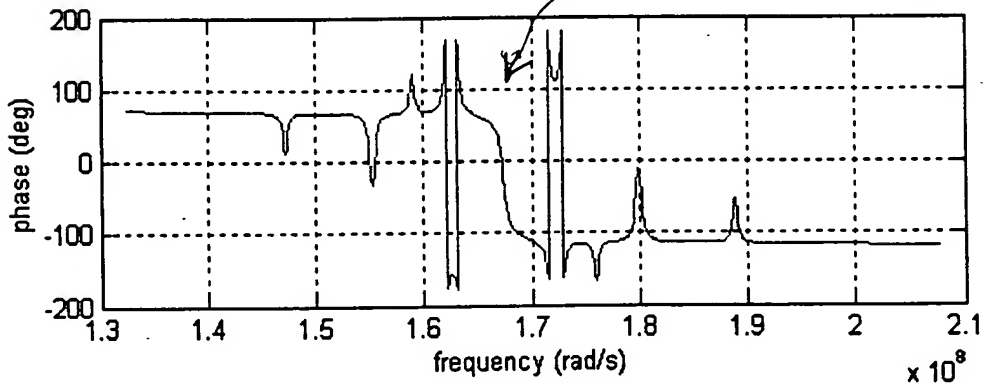


Fig. 7B

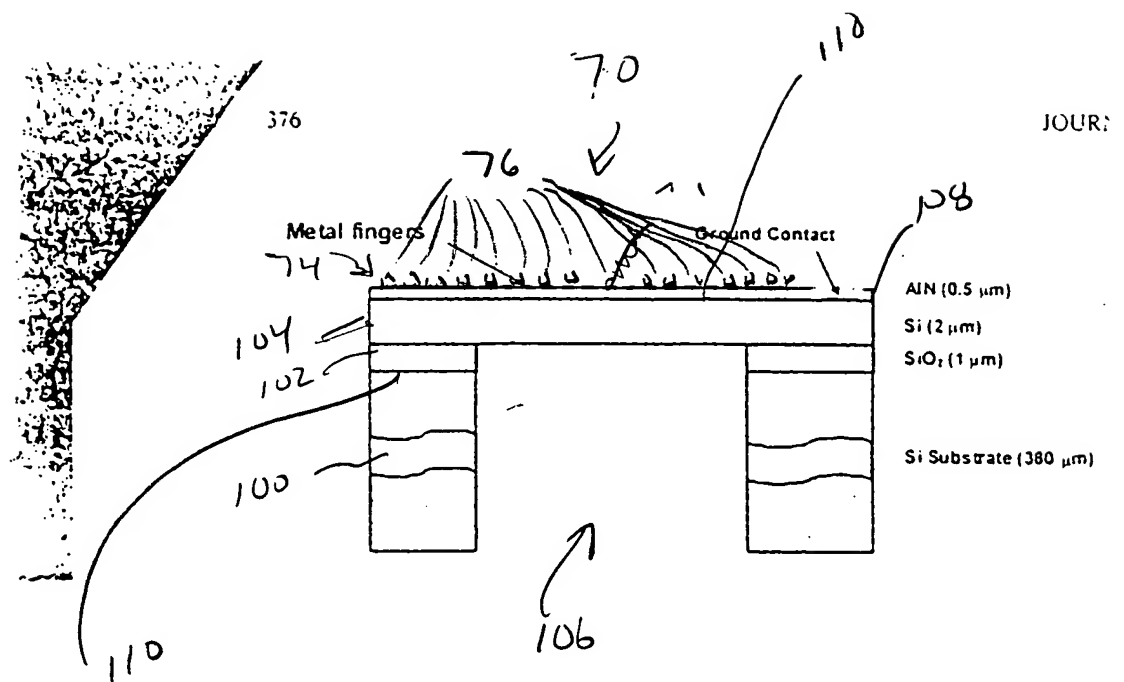


Fig. 8.



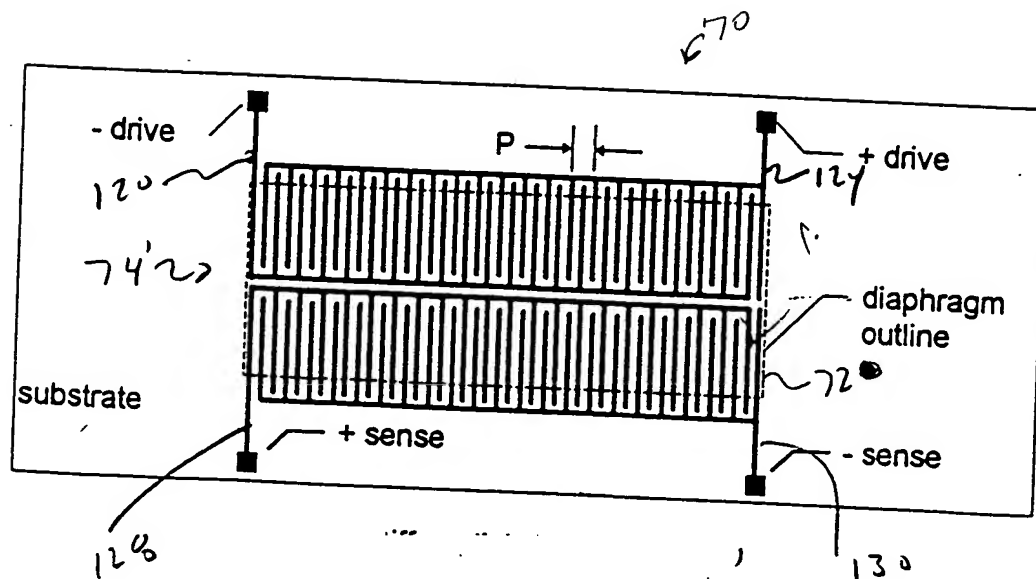
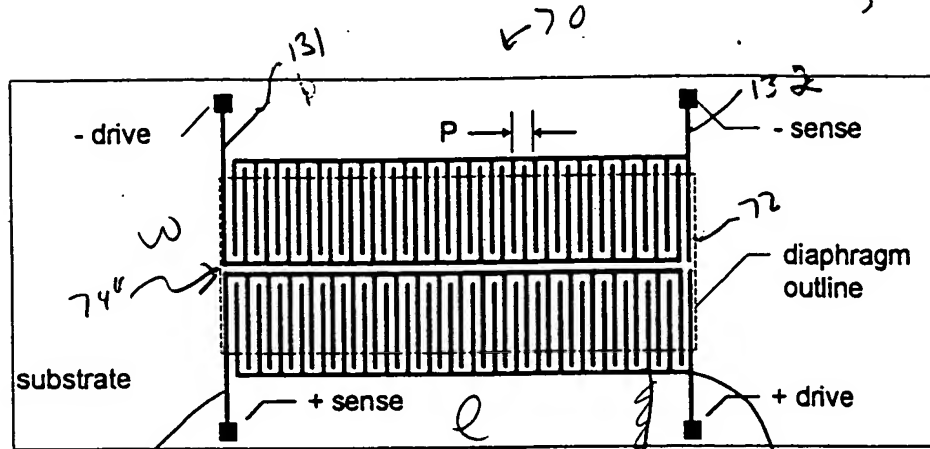


Fig. 9

DRAPER PROPRIETARY



1 Page

Fig. 10

Design 4. Differential signals-interleaved

Figure 6. Recommended design options (continued)

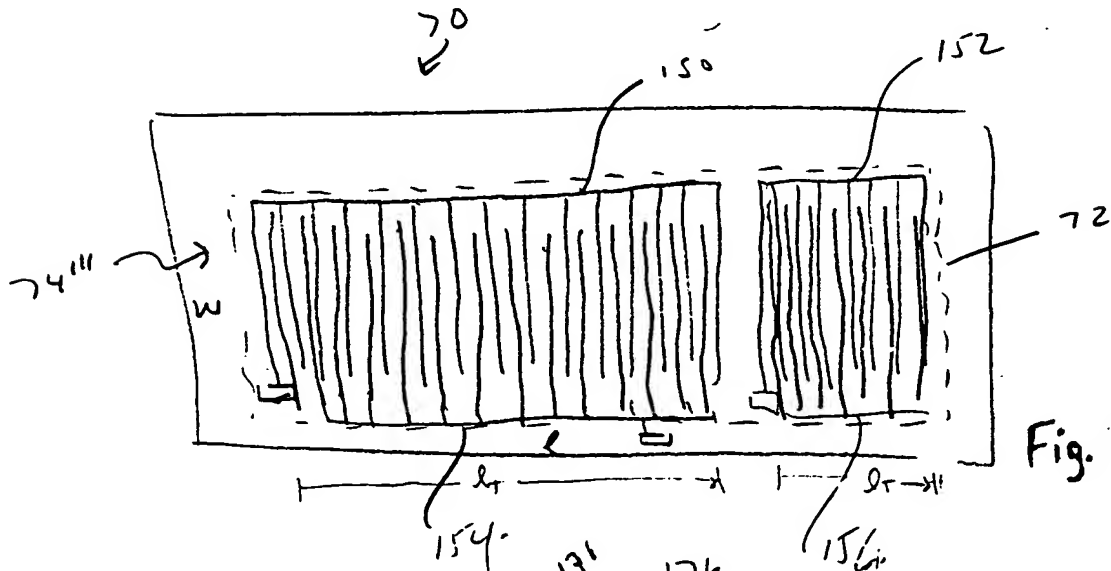


Fig. 11A

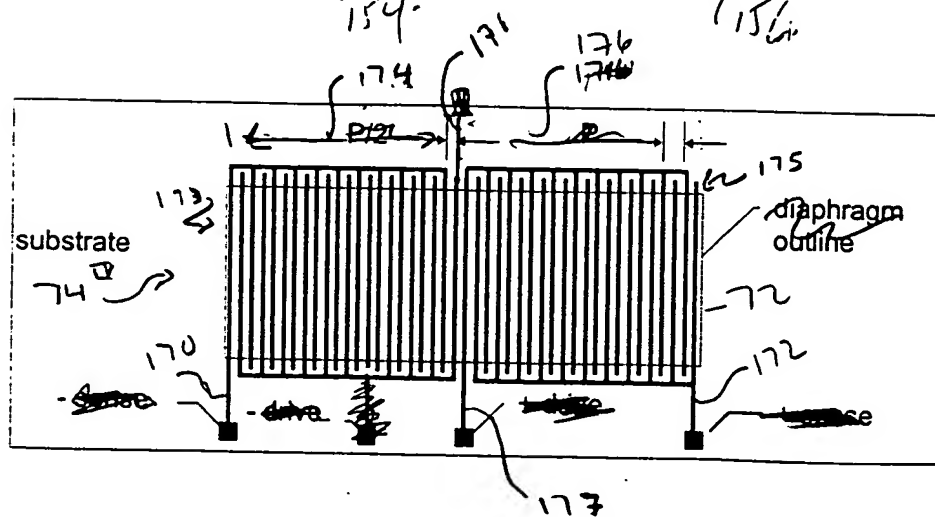
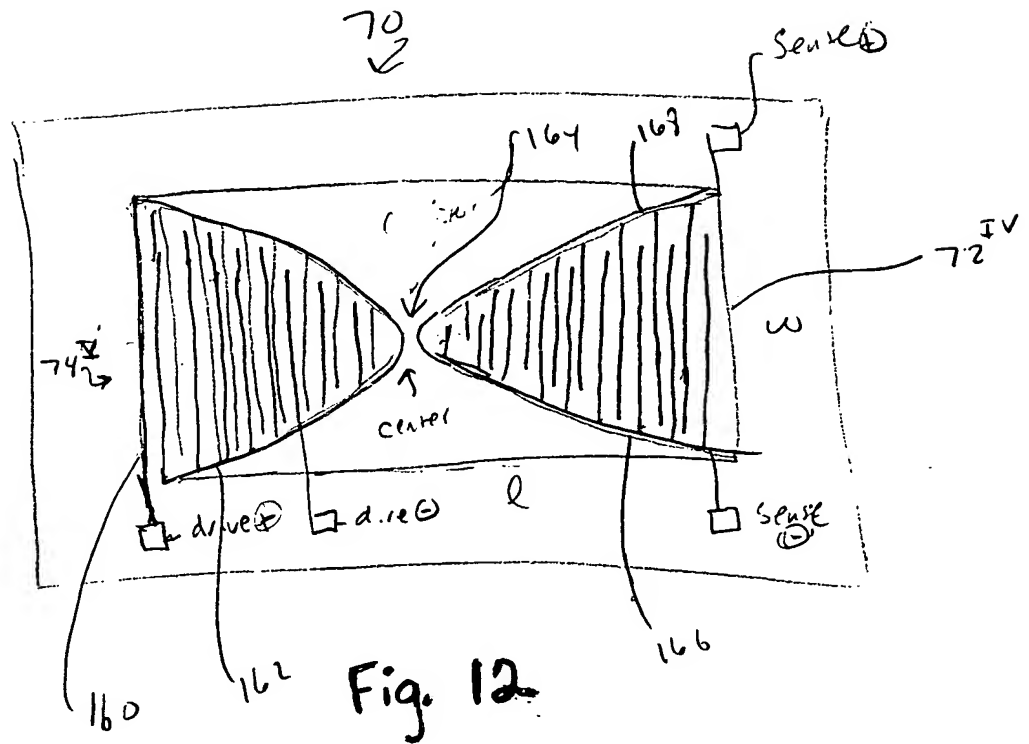


Fig. 11B



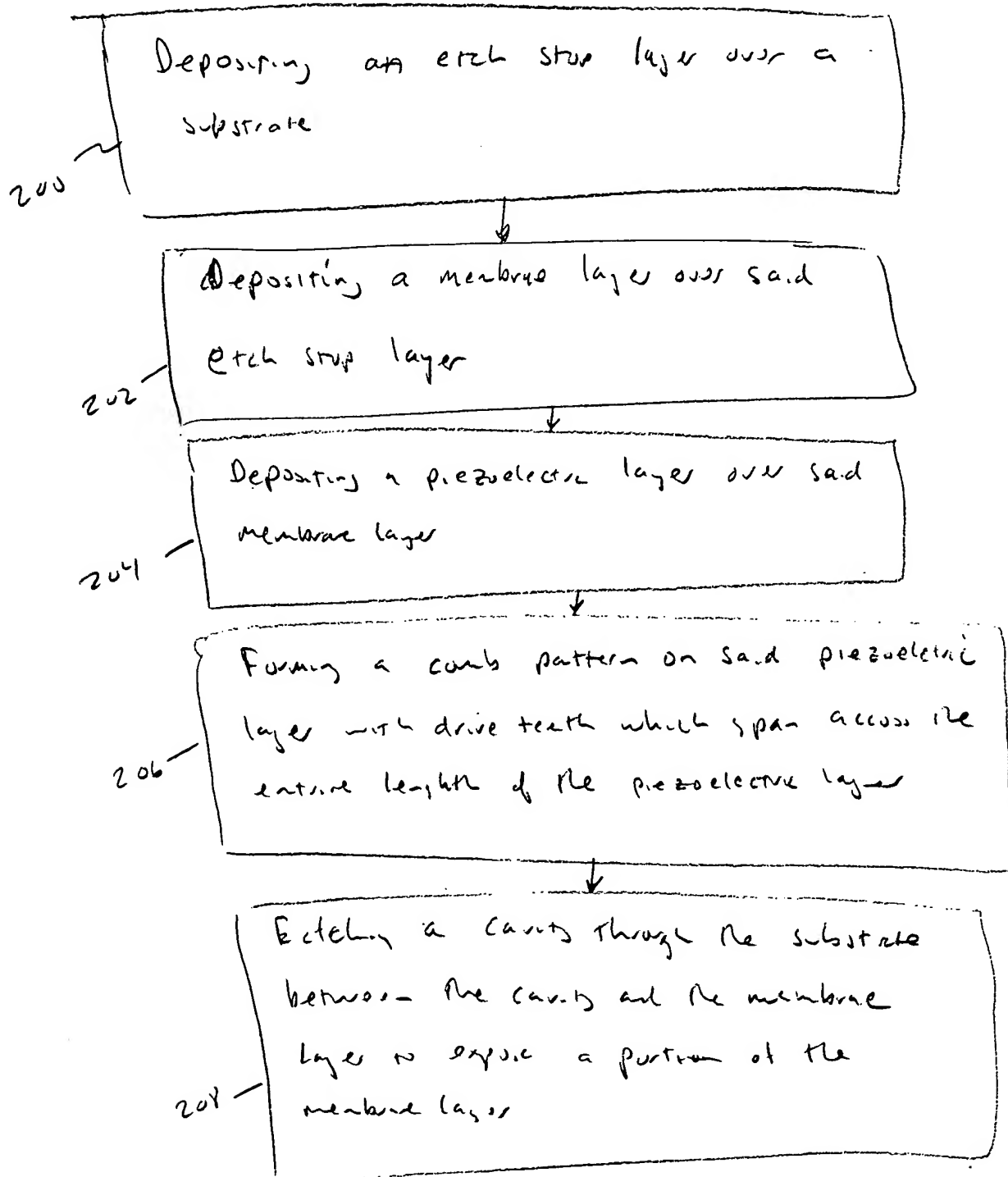


Fig. 13

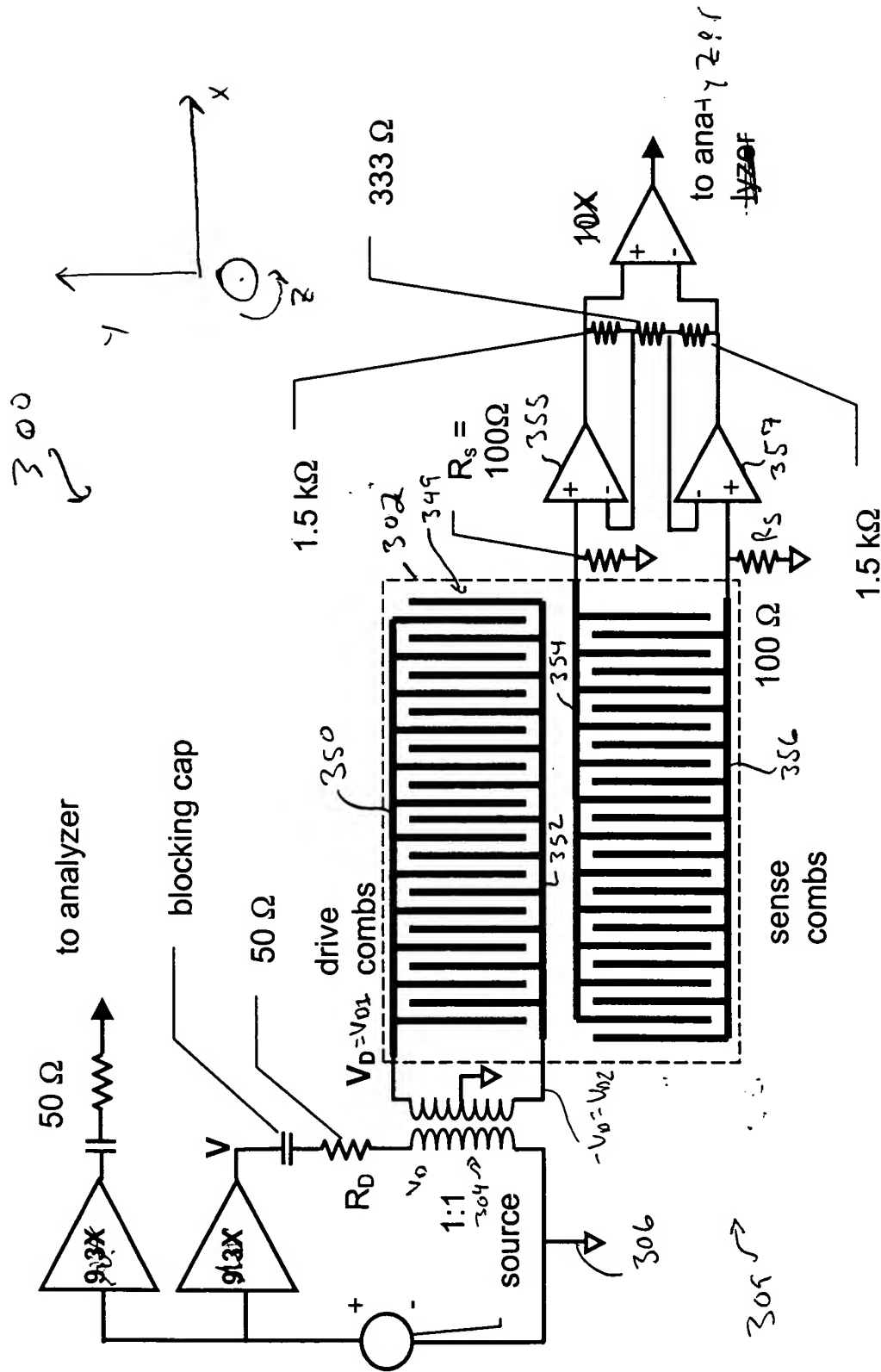


Fig. 14

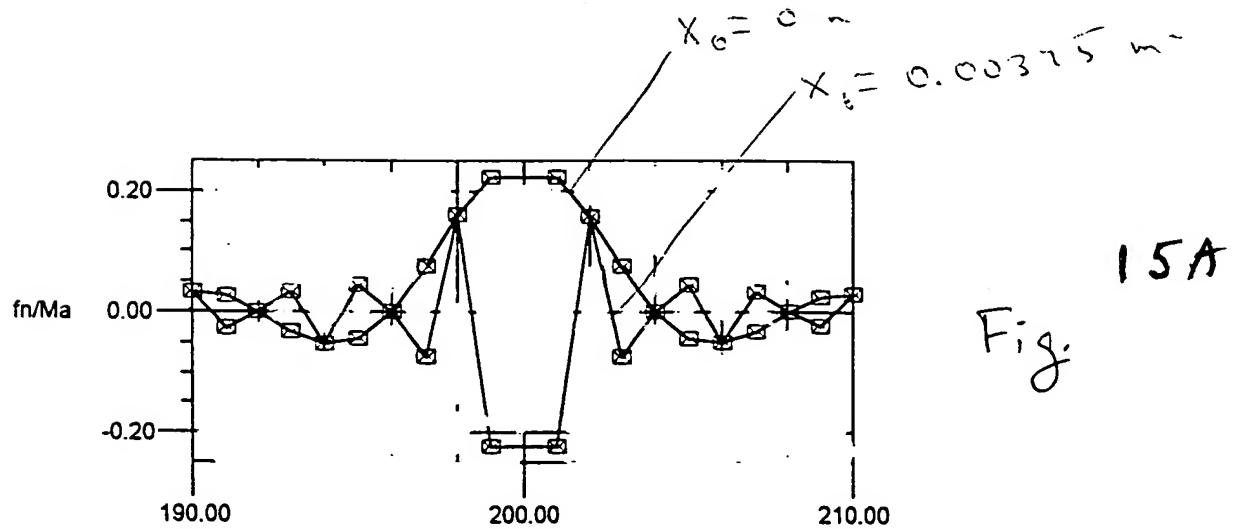


Fig. 15A

$1.90 \times 10^2 < X < 2.10 \times 10^2$   
 $-0.23 < Y < 0.23$

$n$  (mode number)

$$L_T = 0.00125$$

$$Q = 0$$

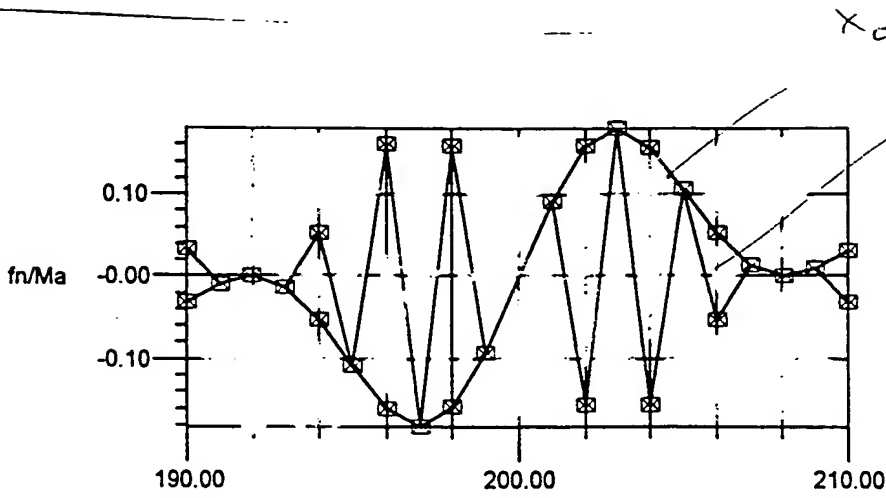


Fig. 15B

$1.90e+2 < X < 2.10e+2$   
 $-0.18 < Y < 0.18$

$$\phi = \pi/2$$

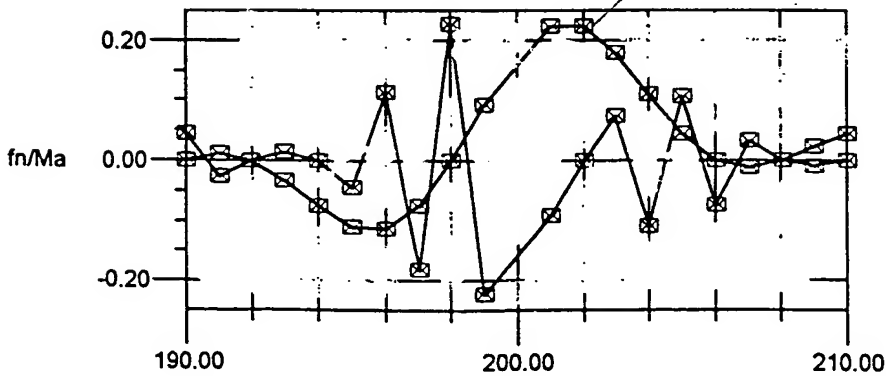


Fig. 15C

$1.90e+2 < X < 2.10e+2$   
 $-0.23 < Y < 0.23$

$$\phi = \pi/4$$

1: %MATLAB CODE FOR FPW CHEMICAL SENSOR MODAL FREQUENCY RESPONSE

2: %

3: %VARMODEEIG.M PARAMETERS FOR MICROCANARY

4: %PLATE WAVE RESONATOR DYNAMIC MODEL

5: %BASED ON FPW5 EXPANDED TO ARBITRARY NUMBER OF MODES BY ELI WEINBERG 7/19/99

6: %SEPTEMBER, 1999. CLOSER SCALING AND DIFFERENTIAL SENSE READING ADDED BY MSW.

7: %SEPARATE DRIVE AND SENSE INPUTS

8: %FIRST CODED 10/13/97

9: % 9/20/02 Calculate eigenvalues (photosensitivity investigation) difference from mechanical only

10: %LATEST RUN 9/20/02

11:

12: % 11/13/01 ATTEMPT THE CHEMICAL SENSOR Q = 100 CASES

13: clear, format compact, format short e, i=sqrt(-1);

14: diary c:\matlab6p1\mw\varmodec.dia

15: rd = 50/4 %xxx

16: %EXTERNAL DRIVE RESISTANCE. THE FACTOR OF FOUR ACCOUNTS FOR THE N=2

17: %TRANSFORMERS AND THE FACT THAT CD IS FOR +/- DRIVE IN PARALLEL.

18: rs = 100/2 %xxx %ONE HALF EXTERNAL SENSE RESISTANCE (ohm)

19: %THE FACTOR OF TWO ACCOUNTS FOR CS IS +/- DRIVE IN PARALLEL.

20: %GAINS BEFORE SOURCE VOLTAGE IS APPLIED TO FPW

21: gamp=1 %INPUT AMPLIFIER-BOTH INPUT AND REFERENCE LEGS HAVE SAME GAIN

22: ginst = 190 %INSTRUMENTATION AMPLIFIER GAIN-

23: %Completely differential amplifier with 10X second stage

24: gtran= 0.5 %TRANSFORMER GAIN

25: %VALUES FOR AIN = 0.5 MICRON, SI = TWO MICRONS

26: mp=2.47e-6 %xxx MASS PER UNIT LENGTH (KG/M)

27: dd = 8.781e-11 %STRUCTURAL RIGIDITY (N/M^2)

28: sq = 400 when bb = 1.033 %xxx %QUALITY FACTOR

29: bb = 1.033 %xxx damping (N-s/m^2)

30: l = 0.0015 %LENGTH OF DIAPHRAGM (m)

31: ld = 3.750001E-5\*19 %LENGTH OF THE DRIVE TRANSDUCER

32: ls = 3.750001E-5\*19 %LENGTH OF THE SENSE TRANSDUCER

33: md=38 %NUMBER OF HALF PERIODS IN TRANSDUCER

34: ms=38 %NUMBER OF HALF PERIODS IN TRANSDUCER

35: pd = 2\*ld/md %PITCH OF DRIVE FINGERS (M)

Fig. 16A



```

36: ps = 2*ls/ms           %PITCH OF SENSE FINGERS (M)
37: %CALCULATE THE MODAL FORCING FUNCTION
38: phi= 0                 %PHASE OF EIGENFREQUENCY (0 FOR PINNED, PI/4 FOR BUILT-IN)
39: thetad= 0              %PHASE OF TRANSDUCER (radians)
40: thetas = 0
41: xd=0                   %STARTING POSITION FOR FORCING COMBS
42: xs=l-ls-xd            %STARTING POSITION OF TRANSDUCER 20
43: %BEWARE CHANGING XD TO ADJUST TOLERANCES.
44: %SCALE FACTOR FOR LENGTH OF SENDER OR RECEIVER COMB
45: %MODEINT IS MSW FUNCTION BASED ON MACSYMA INTEGRATION
46:
47: nmode=input('Enter number of modes ')
48: model=input('Enter number of first mode in model ')
49:
50: for c0=1:nmode
51:     n(c0)=(model-1+c0);
52: end %MODE NUMBER, ROUGHLY NUMBER OF HALF WAVE LENGTHS
53:
54:
55:
56: alph = 0.004874/1.676e5^2
57: %piezo coupling coefficient for 100µ transducer length (coul/m)
58: gamm = 9.39e-11*1.676e5^4 %piezo coupling coefficient (m/V)
59:
60: for c1 = 1:nmode;
61:     pc(c1,1)=modeint(n(c1),md,1,ld,phi,thetad,xd);
62:     pc(c1,2)=modeint(n(c1),ms,1,ls,phi,thetas,xs);
63:     lam(c1)=n(c1)*pi/l; %eigenvalue of plate motion (1/m)
64:     gammad(c1)=gamm*pc(c1,1)/lam(c1)^4;
65:     gammas(c1)=gamm*pc(c1,2)/lam(c1)^4;
66:     alphad(c1)=alph*lam(c1)^2*pc(c1,1);
67:     alphas(c1)=alph*lam(c1)^2*pc(c1,2);
68:     wn(c1)=sqrt(dd/mp)*lam(c1)^2; %eigenfrequency (rad/s)
69:     damping(c1) = bb; %mode damping (N-s/m^2)
70:     k(c1) = mp*wn(c1)^2; %mode stiffness (N/m^2)
71:     checkalpha(c1) = 1-gammad(c1)*k(c1)*0.5*1/alphad(c1);

```

Fig. 16 B

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September 23, 2002

19c

Fig. 16c

```

72: end
73: pc,wn,gammad,gammas,alpha,alphas,checkalpha
74:
75: cs = 7.567e-11*ls/l %CAPACITANCE FROM SENSE COMBS TO GROUND, 2 POLES (F)
76: %EQUAL TO THAT CALCULATED IN TABLE 1. STRAYS MAY ADD MORE.
77: cd = 7.567e-11*ld/l %DRIVE CAPACITANCE (F)
78: rfb=rs*ginst %SENSE AXIS RESISTOR AND INSTRUMENTATION AMPLIFIER
79:
80: %ENTER THE COEFFICIENTS OF THE DERIVATIVES
81: %STATES ARE [QD,QS,V1,X1,V2,X2,V3,X3]
82: ml=zeros(2+2*nmode, 2+2*nmode);
83: mra=zeros(2+2*nmode, 2+2*nmode);
84: ml(1,1)=(cd*rd);
85: ml(2,2)=cs*rs;
86: mra(1,1)=-1;
87: mra(2,2)=-1;
88:
89: for c2=1:nmode
90:     ml(2*c2+1, 2*c2+1)=mp;
91:     ml(2*c2+2, 2*c2+2)=1;
92:     ml(2*c2+1, 1)=rd*k(c2)*gammad(c2);
93:     ml(2*c2+1, 2)=rs*k(c2)*gammas(c2);
94:
95:     mra(2*c2+1, 2*c2+1)=-damping(c2);
96:     mra(2*c2+1, 2*c2+2)=-k(c2);
97:     mra(2*c2+2, 2*c2+1)=1;
98:     mra(1, 2*c2+2)=alpha(c2);
99:     mra(2, 2*c2+2)=alphas(c2);
100: end
101:
102: %ENTER COEFFICIENTS OF DRIVE VOLTAGE
103: mrb=zeros(2*nmode+2, 1);
104: mrb(1)=cd;
105: for c3=1:nmode
106:     mrb(2*c3+1)=k(c3)*gammad(c3);
107: end

```

Fig. 16D

```
108:
109: %ml,mra,mrb
110:
111: %SET UP THE STATE MATRICES
112: invml=inv(ml);
113: checkinvml=invml*ml
114: a=invml*mra
115: b=invml*mrb
116: [evec,eval]=eig(a);
117: damp(eval)
118: %eval
119: %evec
120:
121: %PICK OUT THE DIFFERENCE IN THE EIGENFREQUENCIES
122: yy=sort(damp(eval)); %PLACE THE EIGENVALUES IN ORDER. CHECK THAT THE POLES CORRESPONDING TO TH
E
123: %RC ARE HIGHER THAN THE MECHANICAL POLES
124: for ii = 1:nmode
125:     wnc1(ii)=yy(2*ii-1); %MAKE THE VECTORS OF DIFFERENT LENGTHS SIMILAR AND OMIT THE TWO FASTE
ST POLES
126: end
127: wndiff=wnc1-wn %SHIFT FROM MECHANICAL RESONANCES TO CLOSED LOOP
128:
129: %OUTPUTS ARE AMPLITUDE, SENSE PREAMPLIFIER OUTPUT, AND INPUT CHARGE THROUGH RD
130: %WITH GIN = 1 INPUT IS INPUT TO 10X AMPLIFIER WHICH IS MEASURED BY
131: %ANALYZER
132: gin = 1 %SOURCE TO PREAMP INPUT
133: c=zeros(3, 2+2*nmode);
134: for c4=1:nmode
135:     c(1, 2*c4+2)=1;
136:     c(2, :)=a(2, :)*rfb;
137:     c(3, 1)=.5;
138: end
139: c=c*gamp*gtran*gin
140: d=[0;b(2,:)*rfb; 0]*gamp*gtran*gin
141: %w=logspace(7,9,200);
```

19 E

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September 23, 2002

```

142: nw=1001
143: dw=(1.1*wn(nmode)-0.9*wn(1))/(nw-1);
144: w={0.9*wn(1):dw:1.1*wn(nmode)};
145: wmax=w(length(w))
146: [m1,p1]=unbode(a,b,c,d,1,w);
147: xmax = max(m1(:,1))
148: vmax = max(m1(:,2))
149: figure(1),clf,subplot(2,1,1)
150: semilogy(w,m1(:,2)),grid,xlabel('frequency (rad/s)')
151: ylabel('sense out (V/V)'),axis([w(1),wmax,0.01,max(m1(:,2))])
152: title('SENSE AXIS PREAMPLIFIER OUTPUT')
153: subplot(2,1,2)
154: plot(w,p1(:,2)),grid,xlabel('frequency (rad/s)'), ylabel('phase (deg)')
155: figure(2),clf,subplot(2,1,1)
156: semilogy(w,m1(:,1)),grid,xlabel('frequency (rad/s)')
157: ylabel('amplitude (m/V)'),axis([w(1),wmax,0.01*max(m1(:,1)),max(m1(:,1))])
158: title('MOTION AMPLITUDE')
159: subplot(2,1,2)
160: plot(w,p1(:,1)),grid,xlabel('frequency (rad/s)'), ylabel('phase (deg)')
161: figure(3),clf,subplot(2,1,1)
162: semilogy(w,m1(:,3)),grid,xlabel('frequency (rad/s)')
163: ylabel('charge (C/V)')
164: title('DRIVE CHARGE')
165: subplot(2,1,2)
166: plot(w,p1(:,3)),grid,xlabel('frequency (rad/s)'), ylabel('phase (deg)')
167: % [z,p,k]=ss2zp(a,b,c,d,1) %OBTAIN THE POLES AND ZEROS OF TRANSFER FUNCTION
168: diary off
169:
170:

```

Fig. 16 E

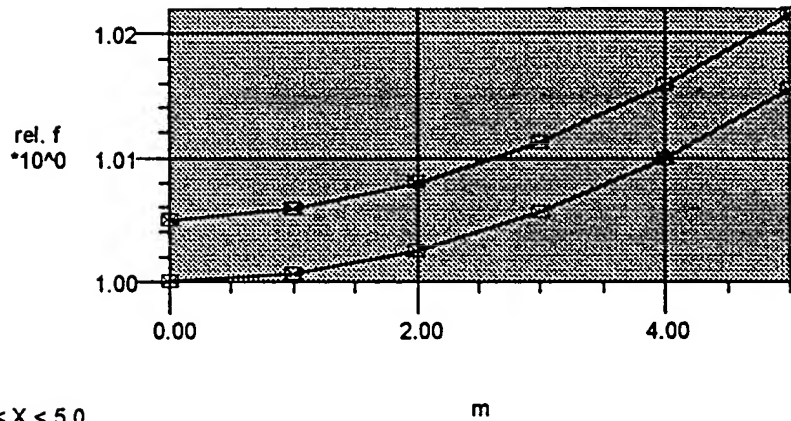
19F-nw

```
1: function [pc]=modeint(n,m,l,lt,phi,theta,xo);
2: %FUNCTION TO OBTAIN THE MODAL FORCING FUNCTION NORMALIZED TO ONE
3: %DERIVED BY MACSYMA AND CODED 10/20/97
4: pc = -lt*sin((pi*lt*n+pi*l*m)*xo-l*lt*theta-l*lt*phi+pi*lt^2....
5:      *n+pi*l*lt*m)/(l*lt))/(pi*(lt*n+l*m))+lt*sin((pi*lt*n+....
6:      pi*l*m)*xo-l*lt*theta-l*lt*phi)/(l*lt))/(pi*(lt*n+l*m))+lt*....
7:      sin((pi*lt*n-pi*l*m)*xo+l*lt*theta-l*lt*phi+pi*lt^2*n-pi....
8:      *l*lt*m)/(l*lt))/(pi*(lt*n-l*m))-lt*sin((pi*lt*n-pi*l*m)*....
9:      xo+l*lt*theta-l*lt*phi)/(l*lt))/(pi*(lt*n-l*m));
10:
```

Fig. 16F

## DRAPER PROPRIETARY

### RELATIVE EIGENFREQUENCIES FOR PLATES



$0.00 < X < 5.0$   
 $1.00 < Y < 1.0$

a.  $\ell/b = 5$

Fig. 17

Plate Bending - clamped boundary

Displacement  
Vol= 9.875e-6

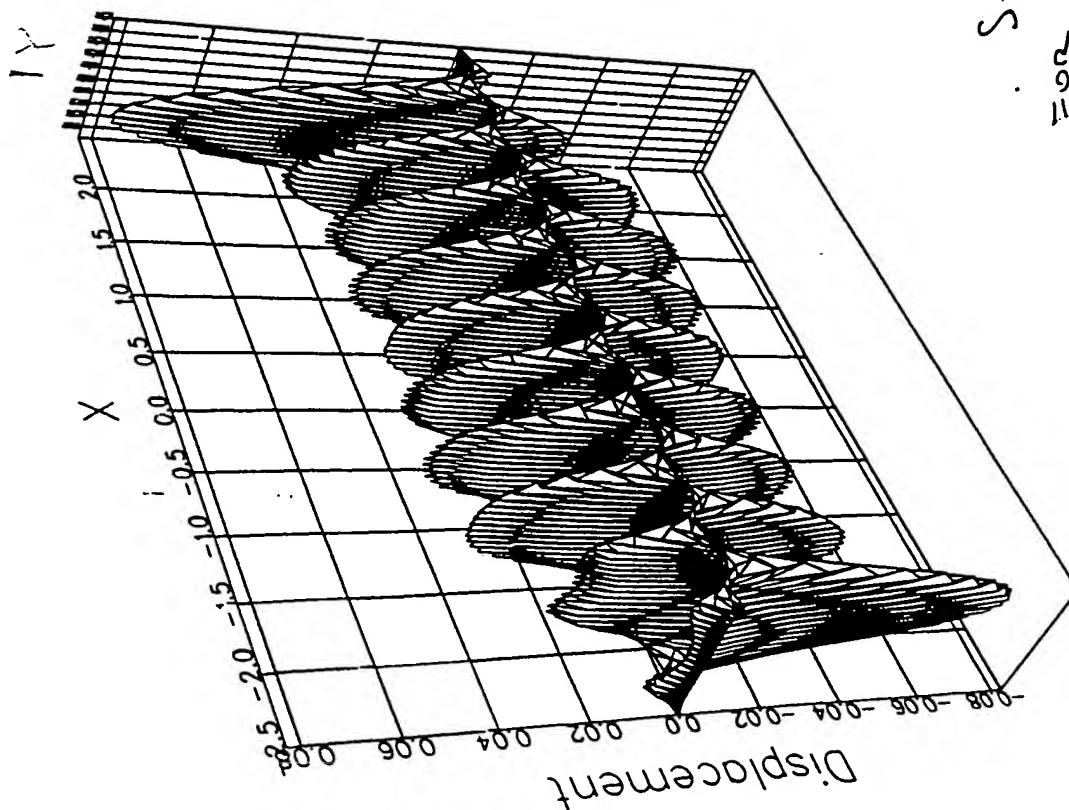


Fig. 18

Static Plate Deflections  
For Sinusoidal Load